

First description of predatory behavior in *Cnodalia harpax* (Araneae: Araneidae)

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Abstract —Predatory behavior in *Cnodalia harpax* is described herein for the first time. Females of the species hanging on two threads span between branches at night were observed in the field. One of them was feeding on a sciarid fly. Observations in the laboratory revealed that *C. harpax* used its long claws to capture prey by hooking the legs, wings, and body. The impalement of prey by claws, previously described in tetragnathid spiders with long claws, had not been observed in *C. harpax*.

Key words — Diptera, foraging mode, forelegs, Okinawa-jima Island, prey capture, Sciaridae, web reduction

Introduction

Forelegs, as well as fangs, are one of the main prey-capturing apparatus in cursorial spiders (Rovner 1980). Modified structures such as adhesive hairs (setae) and erectable spines on forelegs are used for grasping and subduing prey (Eggs et al. 2015; Pekár et al. 2011). Similarly, some species with reduced webs in web weaving groups, such as Araneidae and Tetragnathidae, rely on forelegs for prey capture. For instance, *Pronoides brunneus* Schenkel 1936 (Araneae: Araneidae) and *Metellina ornata* (Chikuni 1955) (Araneae: Tetragnathidae) adults hang on a few threads and capture flying insects and free-living spiders with their forelegs (Tanikawa 1989; Hatsushiba 2001, 2006; Shinkai 1998). Forelegs of orb weavers having reduced web (i.e., their webs lack some elements) sometimes possess modified structures such as an array of long and sharp spines (e.g. “Spiny-clade” *Tetragnatha* spiders in Hawaii: Gillespie 1991a).

Tarsal claws of web-spinning spiders are mainly used to grasp threads (Eberhard 2017), while some species possess elongated claws that may help capturing prey [e.g. *Celaenia penna* (Araneidae): Foster & Gray 1979; *Progradungula carraiensis* (Gradungulidae): Gray 1983; *Trogloraptor marchingtoni* (Trogloraptoridae): Griswold et al. 2012]. A stunning example is found in *Doryonychus raptor* (Araneae: Tetragnathidae), an orb weaver having reduced web endemic to Hawaii. This species directly captures flying and cursorial insects by “impaling” them with long claws on its forelegs (Gillespie 1991b, 1992). Nevertheless, current knowledge on the function of long claw in spiders remains very limited.

Spiders of the genus *Cnodalia* (Araneae: Araneidae) are characterized by elongated prolateral claws on tarsi I and II (Mi et al. 2010). The only species of the genus that occur

in Japan, *Cnodalia harpax* Thorell 1890 (Fig.1) has been recorded from the Amami-osima, Okinawa-jima, Tokunoshima and Okinoerabu-jima Islands (Shinkai et al. 2020). Due to morphological similarities, it is expected that *C. harpax* captures prey in the same manner as *D. raptor* (Tanikawa 2006). Recently, the author had a chance of observing, as well as recording the behavior and prey species of *C. harpax* specimens in the field on Okinawa-jima Island. In addition, I was able to observe the predatory behavior of the species in detail in the laboratory. In this paper, the first description of predatory behavior in *Cnodalia harpax* is provided with a note on its behavior and prey species recorded in the field.

Materials and Methods

Nocturnal field observations were conducted in forests of Kunigami-son, Kunigami-gun District, Okinawa-jima Island, Japan from 21:15 to 22:30 on 8 March 2020. When *C. harpax* specimens were observed, their behavior, posture and any prey items found were recorded by taking photographs and drawing. An adult *C. harpax* female was collected alive and used for behavioral observation. In the laboratory experiment, the spider was placed in a glass vial (diameter: 27.0 mm, height: 55.0 mm) with a piece of twisted paper as scaffold. In accordance with field observation results, dipteran insects were chosen as prey for the experiment. In order to determine whether predatory behavior varies depending on relative prey size, preys from different families (Chironomidae, Empididae, Mycetophilidae and Sciaridae) of different body lengths were offered. Prey-predator size ratio (PPSR) was calculated as prey body length divided by that of the predator. Small-sized preys were offered as several (2–5) individuals at once, while large size prey as single individuals in each trial. All preys were collected on the day of the experiment at Tsukuba-shi, Ibaraki Prefecture, Japan. The

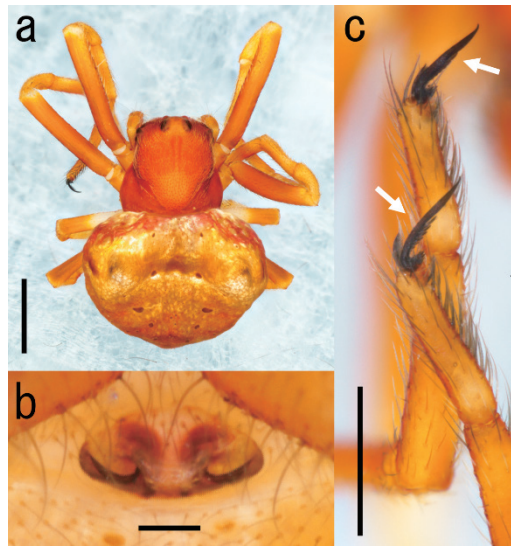


Fig. 1. *Cnodalia harpax* Thorell 1890 (NSMT-Ar. 17339). a, habitus of female, dorsal view; b, epigynum; c, prolateral claws of tarsi I and II (arrows), prolateral view. Scales: 1.0 mm (a), 0.1 mm (b), 0.5 mm (c).



Fig. 2. Waiting posture of *C. harpax* in the field. a, dorsolateral view; b, dorsal view; c, ventral view.

behavior of spiders was studied using video camera recordings (OLYMPUS TG-5; Japan) at 25 °C. Relevant data of the study are available at the Movie Archives of Animal Behavior (<http://www.momop.com/>). The *C. harpax* specimen used in the experiment (Fig. 1) as well as prey items caught by the spider in the field (Fig. 3b) are deposited in the National Museum of Nature and Science collection, Tsukuba, under the same depository number (NSMT-Ar. 17339).

Results

Four female *C. harpax* adults were observed in the field. All of them were found hanging on a V-shaped thread com-

posed of two distinct threads span between evergreen tree branches at heights of 1.6–1.7 m from the ground (Fig. 2). One of the threads with a female was connected with spinnerets and grasped by leg IV, while the other was apart from spinnerets, and held by leg III on the other side (Fig. 2b, c). One of the spiders was feeding on a small prey, but suddenly moved beneath the leaf (Fig. 3a). The prey was identified as a female dark-winged fungus gnat (Diptera: Sciaridae) (Fig. 3b). The moment of prey capture was never observed during field observations.

In total, 13 instances of predation by *C. harpax* were observed in the laboratory (Table 1). Preys that approached the

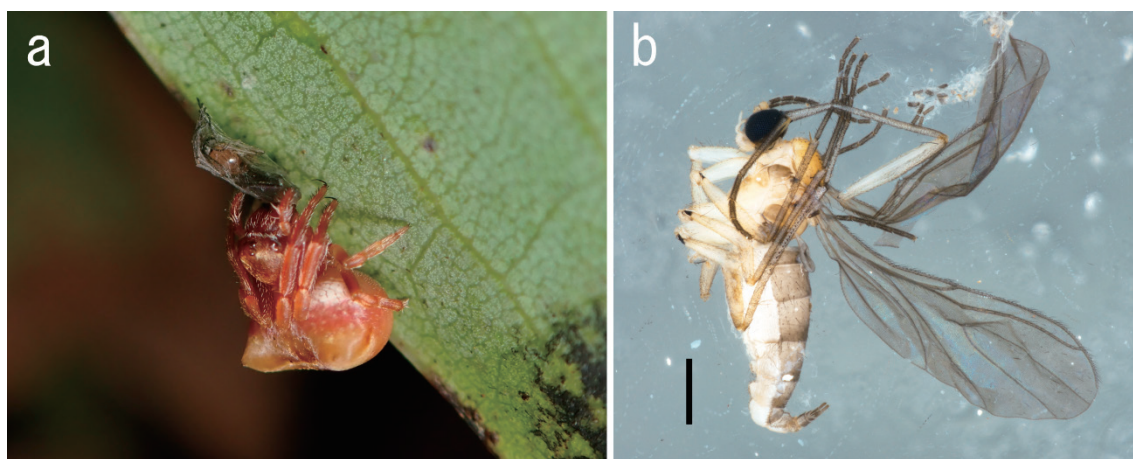


Fig. 3. Foraging case of *C. harpax* observed in the field. a, female adult of *C. harpax* feeding a dark-winged fungus gnat (Diptera: Sciaridae). b, habitus of the sciarid fly eaten by *C. harpax*. Scale=0.5 mm.

Table 1. Basic information of the predatory behavior of *C. harpax* observed in the laboratory.

No. ¹	Date	Sequence of predatory behavior				Prey ⁶	PPSR ⁷
		Prey approach ²	Use of forelegs ³	Use of leg III ⁴	Wrapping ⁵		
1	14-III-2020	F	4	—	—	Sc	0.51
2*	14-III-2020	F	4	—	●	Sc	0.50
3	20-III-2020	F	4	●	●	Ch	3.01
4	22-III-2020	W	4	—	—	Ch	0.66
5*	22-III-2020	W	3	—	—	Ch	0.60
6	22-III-2020	W	4	—	—	Ch	0.95
7	22-III-2020	W	4	—	—	Ch	0.63
8	22-III-2020	W	4	—	—	Ch	0.73
9	25-III-2020	F	4	●	●	Ch	2.40
10	25-III-2020	F	4	●	●	My	1.15
11	27-III-2020	W	4	●	—	Em	0.91
12	27-III-2020	F	4	●	—	Em	0.87
13	30-III-2020	F	4	●	●	Ch	2.30

¹: Number of each observations. Asterisks indicate that the predator captured the second prey (No. 2 or 5) before consuming the first prey (No. 1 or 4).

²: The way prey approached the predator. F: flying; W: wandering on threads.

³: Number of frontal legs (I and II) used for prey capture.

⁴: Whether legs III were used (●) or not (—) to capture a prey before the first bite.

⁵: Whether *C. harpax* wrapped a prey (●) or not (—) after the first bite.

⁶: Families of prey insects (Diptera) offered. Em: Empididae; Ch: Chironomidae; Sc: Sciaridae; My: Mycetophilidae.

⁷: Prey-predator size ratio.

spider either by flying (n=7/13; also see Suzuki 2020a) or wandering on threads (n=6/13; also see Suzuki 2020b) were captured. While preys were approaching, the spider always stayed in the same place without wandering in the vial. When a prey got close to the spider, the forelegs of the spider were immediately raised over the carapace and stretched

out towards the prey (Figs. 4b, 5b). Consequently, its long claws hooked the legs, wings, or body of the prey (Figs. 4c–e, 5c–d). This hooking behavior was performed regardless of relative prey size (PPSR: 0.50–3.01; Table 1). In most cases all forelegs (both legs I and II) were used for grasping prey (n=12/13; Table 1). Leg pair III was also used when holding

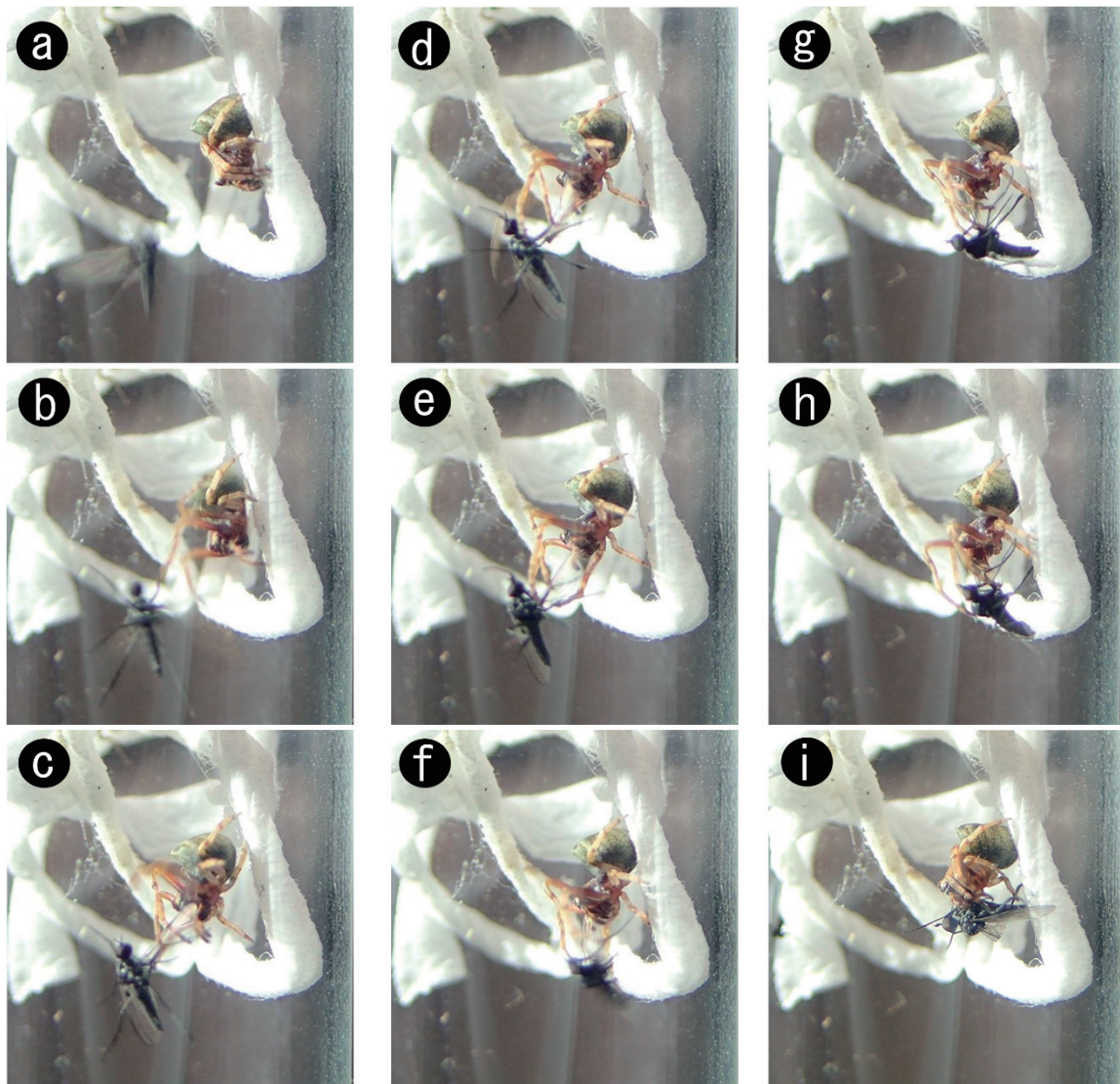


Fig. 4. Behavioral sequence of a predation on an Empidid fly by *C. harpax*. a, waiting posture; b, forelegs raised; c-e, claws of forelegs hooking legs and wings of the prey; f-h, scooping the prey; i, biting. The related movie is available at the Movie Archive of Animal Behavior (<http://www.momo-p.com/index.php?movieid=momo200408ch01b&embed=on>).

large sized prey (PPSR: 1.15–3.01; Table 1).

After grasping prey, the spider quickly scooped it and bit the thorax with its fangs (Figs. 4i, 5f). It did not wrap small sized prey (Table 1). One exception was seen when the spider caught the second prey before consuming the first one: it then wrapped two prey items at the same time (Table 1; No. 2). Large-sized preys were wrapped with silk threads soon after the first bite (Table 1). After a prey was immobilized with a bite or silk, the spider crushed the prey body with a pair of chelicerae before consuming it.

Discussion

The present study reports observations on the predatory behavior of *Cnodalia harpax* for the first time. The results of field observation suggest that the species does not build an orb type web but hangs on two thread lines between branches to capture flying insects, such as sciarid flies. This foraging mode is quite similar to that of *Pronoides brunneus* reported by Tanikawa (1989), except that the latter does not have elongated claws. The laboratory experiment revealed that the species captures prey with elongated claws on tarsi I and II hooking the legs, wing and body of prey (Figs. 4, 5).

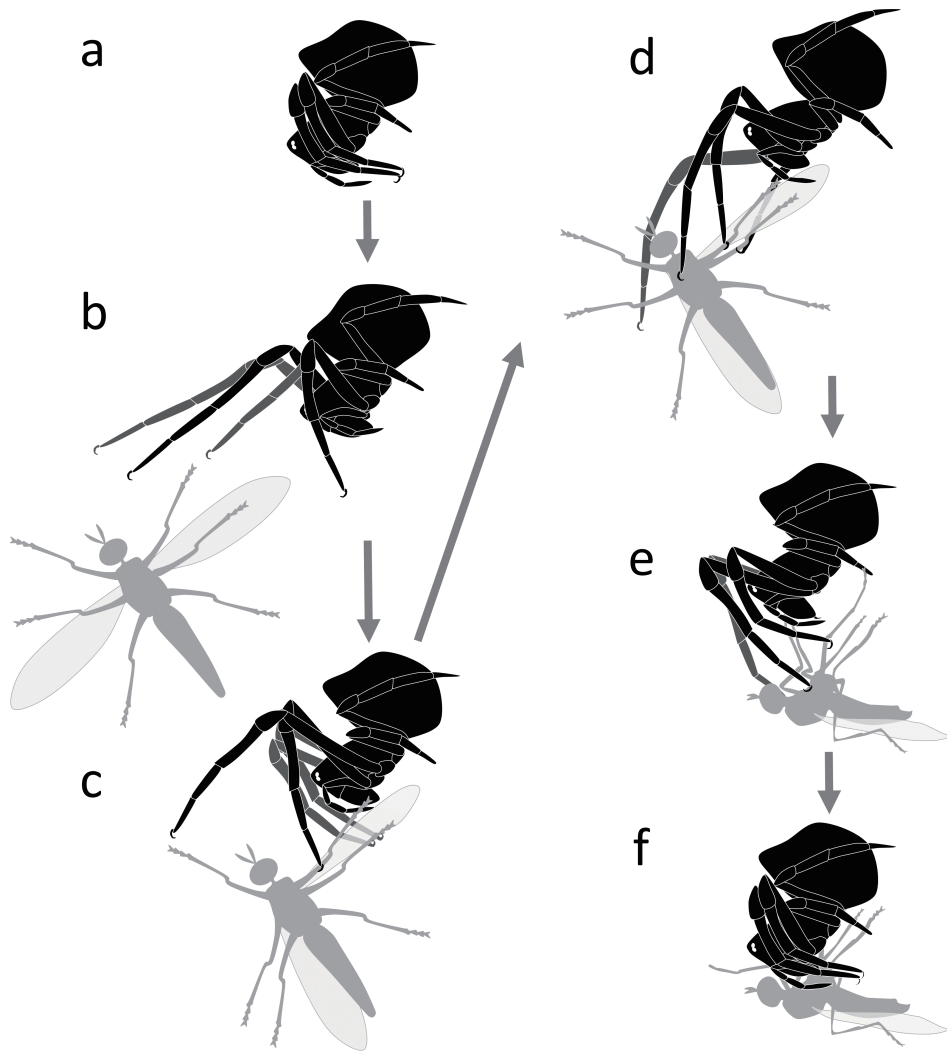


Fig. 5. Schematic drawing of the predatory behavior of *C. harpax*. a, resting posture; b, forelegs raised; c-d, claws of forelegs hooking legs and wings of the prey; e, scooping the prey; f, biting.

The way *C. harpax* uses its claws is similar to *P. carraiensis* “scooping” behavior (Gray 1983) but can be clearly distinguished from “impalement” as seen in the long-clawed *D. raptor* (Gillespie 1991b). To the best of my knowledge, observations of the present study demonstrate the first evidence of long claw function in araneid spiders.

Whether such foraging behavior with modified claws is linked to dietary specialization or not remains an open question. Some long-clawed spiders are thought to be stenophagous predators: *Celaenia* a moth-specialist (Foster & Gray 1979) and *T. marchingtoni* a potential specialist that rejected various prey taxa offered in the laboratory (Griswold et al. 2012). The results of laboratory experiment showed that *C. harpax* accepted various Dipteran species as prey (4 families

from 2 suborders), but it is still not clear how the spider responds to other invertebrate taxa.

Spiders having reduced web sometimes acquire the mechanism of prey attraction as well as modified foraging apparatus (Foster & Gray 1979; Haynes et al. 2002). For instance, *Kaira* spiders (Araneidae) are suggested to attract males of specific moth species with sex pheromone-like chemicals and capture them with forelegs (Levi 1993). Though it is based on single observation, the fact that *C. harpax* fed on a sciarid fly female seems to deny the possibility of the presence of such a prey attraction with pheromone. It is also possible that *C. harpax* captures Dipteran insects attempting to hang on the spider’s threads (Schelt & Mulder 2000; Lenteren & Schettino 2003), rather than attracting prey. Further

studies on natural diet, prey preference and predatory behavior in field are needed to determine diet breadth and foraging mode of *C. harpax*.

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References

- Cárdenas, M., Šedo, O. & Pekár, S. 2014. Is there ontogenetic shift in the capture traits of a prey-specialized ant-eating spider? *J. Zool.*, 293: 234–242.
- Eberhard, W. 2017. How orb-weavers find and grasp silk lines. *J. Arachnol.*, 45: 145–151.
- Foster, R. R. & Gray, M. R. 1979. *Progradungula*, a New Cribellate Genus of the Spider Family Gradungulidae (Araneae). *Aust. J. Zool.*, 27: 1051–71.
- Gillespie, R. G. 1991a. Hawaiian spiders of the genus *Tetragnatha*: I. Spiny clade. *J. Arachnol.*, 19: 174–209.
- Gillespie, R. G. 1991b. Predation through impalement of prey: the foraging behavior of *Doryonychus raptor* (Araneae, Tetragnathidae). *Psyche*, 98: 337–350.
- Gillespie, R. G. 1992. Impaled prey. *Nature*, 355: 212–213.
- Gray, M. R. 1983. The male of *Progradungula carraiensis* Forster and Gray (Araneae, Gradungulidae) with observations on the web and prey capture. *Proc. Linn. Soc. N.S.W.*, 107: 51–58.
- Griswold, C. E., Audisio, T. & Ledford, J. M. 2012. An extraordinary new family of spiders from caves in the Pacific Northwest (Araneae, Trogloraptoridae, new family). *Zookeys*, 215: 77–102.
- Hatsushiba, S. 2001. *Pronoides brunneus* Schenkel 1936 (Araneae: Araneidae) ate *Phycosoma mustelinum* (Simon 1889) (Araneae: Theridiidae). *Kishidaia*, 81: 38–39.
- Hatsushiba, S. 2006. Foraging cases of *Pronoides brunneus* Schenkel 1936 (Araneae: Araneidae). *Kishidaia*, 90: 24–25. (in Japanese)
- Haynes, K. F., Gemenio, C., Yeargan, K. V., Millar, J. G. & Jhonson, K. M. 2002. Aggressive chemical mimicry of moth pheromones by a bolas spider: how does this specialist predator attract more than one species of prey? *Chemoecology*, 12: 99–105.
- Lenteren, J. van & Schettino, M. 2003. Kinky sex and suicidal mating behaviour in *Aphidoletes aphidimyza*. *Entomolog. Ber.*, 63: 143–146.
- Levi, H. W. 1993. The orb-weaver genus *Kaira* (Araneae: Araneidae). *J. Arachnol.*, 21: 209–225.
- Mi, X. Q., Peng, X. J. & Yin, C. M. 2010. The spider genus *Cnodalia* (Araneae: Araneidae) in China. *Zootaxa*, 2452: 59–66.
- Pekár, S., Sobotník, J. & Lubin, Y. 2011. Armoured spiderman: morphological and behavioral adaptations of a specialized araneophagous predator (Araneae: Palpimanidae). *Naturwissenschaften*, 98: 593–603.
- Rovner, J. S. 1980. Morphological and ethological adaptations for prey capture in wolf spiders (Araneae, Lycosidae). *J. Arachnol.*, 8: 201–215.
- Schelt, J. van & Mulder, S. 2000. Improved methods of testing and release of *Aphidoletes aphidimyza* (Rondani) (Dipt.: Cecidomyiidae) for aphid control in glasshouses. *Eur. J. Entomol.*, 97: 511–515.
- Shinkai, A. 1998. The web structure and the predatory behavior of *Menosira ornate* Chikuni (Araneae: Tetragnathidae). *Acta Arachnol.*, 47: 53–57. (in Japanese with English title and abstract)
- Shinkai, A., Andoh, A., Tanikawa, A., Ikeda, H. & Kuwata, T. 2020. Japanese spiders ver. 2020. Self-published. (in Japanese)
- Suzuki, Y. 2020a. Predatory behavior of *Cnodalia harpax*. Movie Archive of Animal Behavior Data No.: momo200408ch01b (<http://www.momo-p.com/myvideo/showdetail.php?movieid=momo-200408ch01b>).
- Suzuki, Y. 2020b. Prey-capturing behavior of *Cnodalia harpax* (2). Movie Archive of Animal Behavior Data No.: momo200408ch02b (<http://www.momo-p.com/index.php?movieid=momo200408ch-02b&embed=on>).
- Tanikawa, A. 1989. The hunting method of *Pronoides minutus* (Saito, 1939) (Araneae: Araneidae). *Atypus*, 94: 1–4. (in Japanese with English title)
- Tanikawa, A. 2006. Rediscovery of *Cnodalia halpax* [sic] (Araneae: Araneidae) after an interval of 116 years. *Acta Arachnol.*, 55: 21–22.
- Tanikawa, A. 2007. The first description of a male of *Cnodalia halpax* (Araneae: Araneidae). *Acta Arachnol.*, 56: 71–72.

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